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# 2015 CRC Aviation Meetings Particle Count Limits Recommendation for Aviation Fuel

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Unclassified

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# Bagram Airfield



photo courtesy of Army Petroleum Center

# Contamination



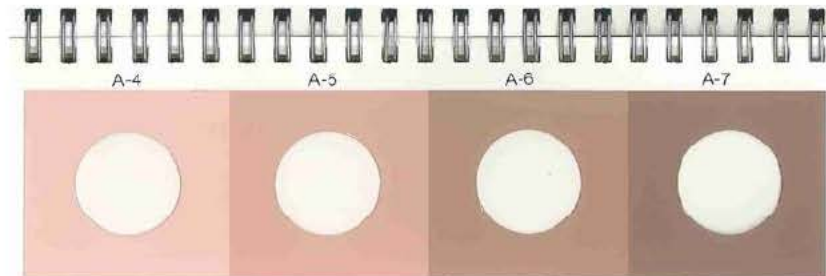
photos courtesy of Army Petroleum Center



- ASTM D2276 – Particulate Contamination in Aviation Fuel by Line Sampling
  - gravimetric limit 1.0 mg/L (MIL-STD-3004, MIL-DTL-83133)
    - JP-4 and JP-5 (MIL-T-5624G - 5 NOV 1965)
  - color rating > 4 on any color scale (FM 10-67-1)
- ASTM D5452 – Particulate Contamination in Aviation Fuels by Laboratory Filtration
  - gravimetric limit 1.0 mg/L (MIL-STD-3004)
- ASTM D3240 – Undissolved Water in Aviation Turbine Fuels
  - 10 PPM (MIL-STD-3004, ATP 4-43)
- ASTM D4176 – Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
  - Clear and Bright

- Drawbacks:

- Operator subjectivity (ASTM D2276 color comparison)



- Lack of detail (ASTM D2276 gravimetric)



- Large sample volumes (500mL – 5 Liters)
- Potential contamination
- Time consuming

- MIL-DTL-83133, MIL-DTL-5624, and DEF STAN 91-91 include a requirement to only report particle counting measurements.
- IP 564 – Parker ACM20
- IP 565/ASTM D7619 – Stanhope-Seta AvCount
- IP 577 – Pamas S40



# Particle Counter Methodology



- Particle counts are taken utilizing calibration methodologies and standardized cleanliness code ratings
  - ISO 11171
  - ISO 4406
- Particle Count ISO 4406 code  
19/17/14/13 limits of 4µm (c) /6µm (c)/14µm (c)/30µm (c)

Number of particles per millilitre		Scale number
More than	Up to and including	
2 500 000		>28
1 300 000	2 500 000	28
640 000	1 300 000	27
320 000	640 000	26
160 000	320 000	25
80 000	160 000	24
40 000	80 000	23
20 000	40 000	22
10 000	20 000	21
5 000	10 000	20
2 500	5 000	19
1 300	2 500	18
640	1 300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2,5	5	9
1,3	2,5	8
0,64	1,3	7
0,32	0,64	6
0,16	0,32	5
0,08	0,16	4
0,04	0,08	3
0,02	0,04	2
0,01	0,02	1
0,00	0,01	0



# Proposed Limits



	Receipt	Vehicle Fuel Tank	Fuel Injector
<b>Aviation Fuel</b>			
DEF (AUST) 5695B		18/16/13	
Parker	18/16/13	14/10/7	
Pamas / Parker / Particle Solutions	19/17/12		
US Army / US Navy / US Air Force	19/17/14/13*		
<b>Diesel Fuel</b>			
World Wide Fuel Charter 5th		18/16/13	
DEF (AUST) 5695B		18/16/13	
Caterpillar		18/16/13	
Detroit Diesel		18/16/13	
MTU		18/17/14	
Bosch/Cummins		18/16/13	
Donaldson	22/21/18	14/13/11	12/9/6
Pall	17/15/12	15/14/11	12/9/6 11/8/7

\* 4µm (c)/ 6µm (c)/ 14µm (c)/ 30µm (c)

- September 2012 – March 2015
- ASTM D5452 Laboratory filtration
- IP 564 – Parker ACM20 (59 samples only)
- IP 565/ASTM D7619 – Stanhope-Seta AvCount
- 1414 samples analyzed

- 1414 samples analyzed
- 1209 samples passed both gravimetric and particle count
- 205 samples failed particle count or gravimetric
  - 161 out of 205 samples failed particle count
  - 135 out of 205 samples failed gravimetric
  - 91 out of 205 samples failed both particle count and gravimetric
- 44 **False negatives** (fails gravimetric, passes particle count)
- 70 False positives (fails particle count, passes gravimetric)



- 44 False negatives (fails gravimetric, passes particle count)
- ASTM D5452 repeatability (r) 0.0-0.6 mg/L
  - $r = 0.415x^{0.5}$
  - $r$  at 1.0 mg/L = 0.415 mg/L
    - repeatability formula based on 5 liter sample
- 33 samples may be lower than 1.0 mg/L based on repeatability calculations.
- 11 samples have high gravimetric reading that is not accounted for by particle count data.
- Particles not seen by particle counter
  - Particle greater than 70 $\mu$ m (c) (Stanhope Seta) - 200 $\mu$ m (c) (Parker)
  - Particles less than 4 $\mu$ m (c)

- 70 False positives (fails particle count, passes gravimetric)
  - 28 samples gravimetric data may be greater than 1.0 mg/L based on repeatability calculations.
  - 2 diesel fuels high in 4 $\mu$ m (c) channel
  - 66 aviation fuels high in 6 $\mu$ m (c), 14 $\mu$ m (c), and/or 30 $\mu$ m (c) channels indicating free water contamination
  - Analyzed to determine if free water contributed to the high particle counts
    - 6 of 66 fuel samples confirmed >5 ppm free water contamination
    - 8 of 66 fuel samples with 1-5 ppm free water
    - 25 of 66 fuel samples confirmed to be absent of free water
    - 27 of 66 fuel samples untested

- 110 samples analyzed
- 105 samples passed both gravimetric and particle count
- 3 samples failed particle count
- 3 samples failed gravimetric
- 1 samples failed both particle count and gravimetric
- 2 False positives (high particle count not correlated to gravimetric)
- 2 False negatives (high gravimetric not correlated to particle count)





- 2 False negatives (fails gravimetric, passes particle count)
  - 1 samples may be lower than 1.0 mg/L based on repeatability calculations.
  - 1 sample had high gravimetric reading that is not accounted for by particle count data.
- 2 False positives (fails particle count, passes gravimetric)
  - 1 aviation fuels high in 14 $\mu$ m (c) channels indicating free water contamination



- Proposed limits for particle counting in agreement with existing fuel specification limits 92% of the time (96% USAF data).
- Free water measurements need to be taken to account for false positives.
- Duplicate gravimetric measurements need to be taken to determine if poor measurement repeatability accounts for false negatives.
- Photograph failed gravimetric filter pads for visual inspection.

- Tri-Service POL Technical Steering Committee recommends the 19/17/14/13 limits for the 4 $\mu$ m (c)/ 6 $\mu$ m (c)/ 14 $\mu$ m (c)/ 30 $\mu$ m (c) size channels as an acceptable method for particulate matter with the stipulation (requirement) to perform follow on testing for particulate matter via ASTM D5452 and water via ASTM D3240 for product exceeding the limits.





- Backup Slides

- 1414 samples analyzed
- 982 samples passed both gravimetric and particle count
- 432 samples failed particle count or gravimetric
  - 407 out of 432 samples failed particle count
  - 135 out of 432 samples failed gravimetric
  - 110 out of 432 samples failed both particle count and gravimetric
- 25 False negatives (fails gravimetric, passes particle count)
  - 43% reduction
- 297 **False positives** (fails particle count, passes gravimetric)
  - 324% increase

- 1414 samples analyzed
- 806 samples passed both gravimetric and particle count
- 608 samples failed particle count or gravimetric
  - 407 out of 608 samples failed particle count
  - 459 out of 608 samples failed gravimetric
  - 258 out of 608 samples failed both particle count and gravimetric
- 201 False negatives (fails gravimetric, passes particle count)
- 149 **False positives** (fails particle count, passes gravimetric)



- 201 False negatives (fails gravimetric, passes particle count)
- ASTM D5452 repeatability (r) 0.0-0.6 mg/L
  - $r = 0.415x^{0.5}$
  - $r$  at 0.5 mg/L = 0.293 mg/L
    - repeatability formula based on 5 liter sample
- 165 samples may be lower than 0.5 mg/L based on repeatability calculations.
- 36 samples have high gravimetric reading that is not accounted for by particle count data.
- Particles not seen by particle counter
  - Particle greater than 70 $\mu$ m (c) (Stanhope Seta) - 200 $\mu$ m (c) (Parker)
  - Particles less than 4 $\mu$ m (c)

- 149 False positives (fails particle count, passes gravimetric)
  - 91 samples gravimetric data may be greater than 0.5 mg/L based on repeatability calculations.
  - 5 diesel fuels



- Low levels of free water can have a large impact in particle count readings, this may account for an unknown number of the false positive readings.